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Pros and Cons of Gas Production Through Pyrolysis

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Workshops

Pyrobiomethane Objectives

- Achieve High Economic Value
  - Produce a high value biochar product
  - Produce more biogas
  - Reduce residual biosolids
- Be User Friendly
  - Use proven technology
    - Anaerobic digestion
    - Biosolids drying
    - Biogas treatment
- Be Environmentally Sustainable
  - Produce more biogas
  - Produce a nutrient rich soil amendment
- Socially Acceptable
  - Produce a less odorous product

Wastewater Plants Are Being Viewed as Resource Centers

Fuel

Energy
(Heat, Power)

Solar and Wind

Organic
Waste

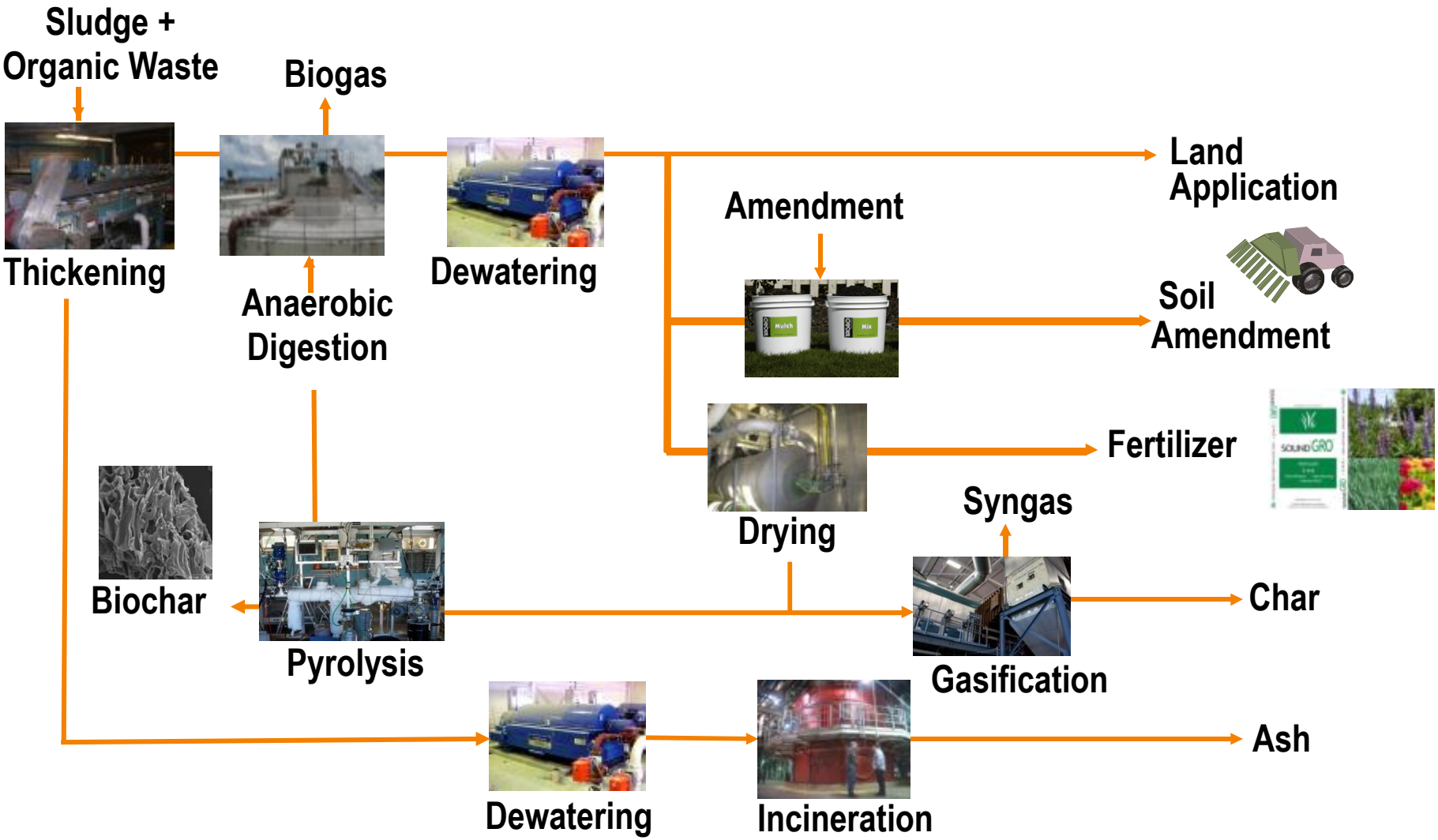
Resource Supply
(fuel line)

Fertilizer &
Nutrients

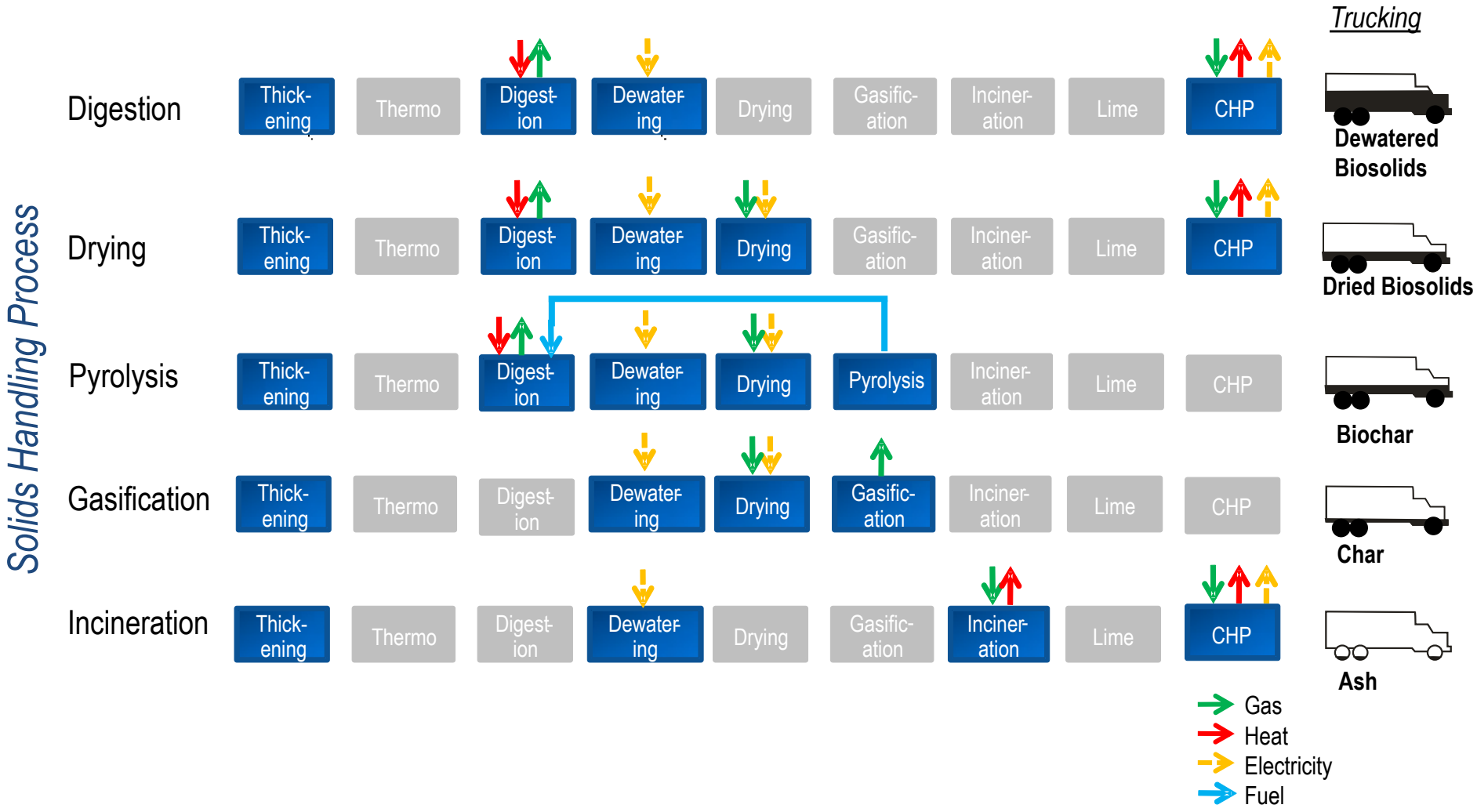
BNEW (**B**iosolids, **N**utrients, **E**nergy, **W**ater) **Center**

Reclaimed Water
& Hydrothermal

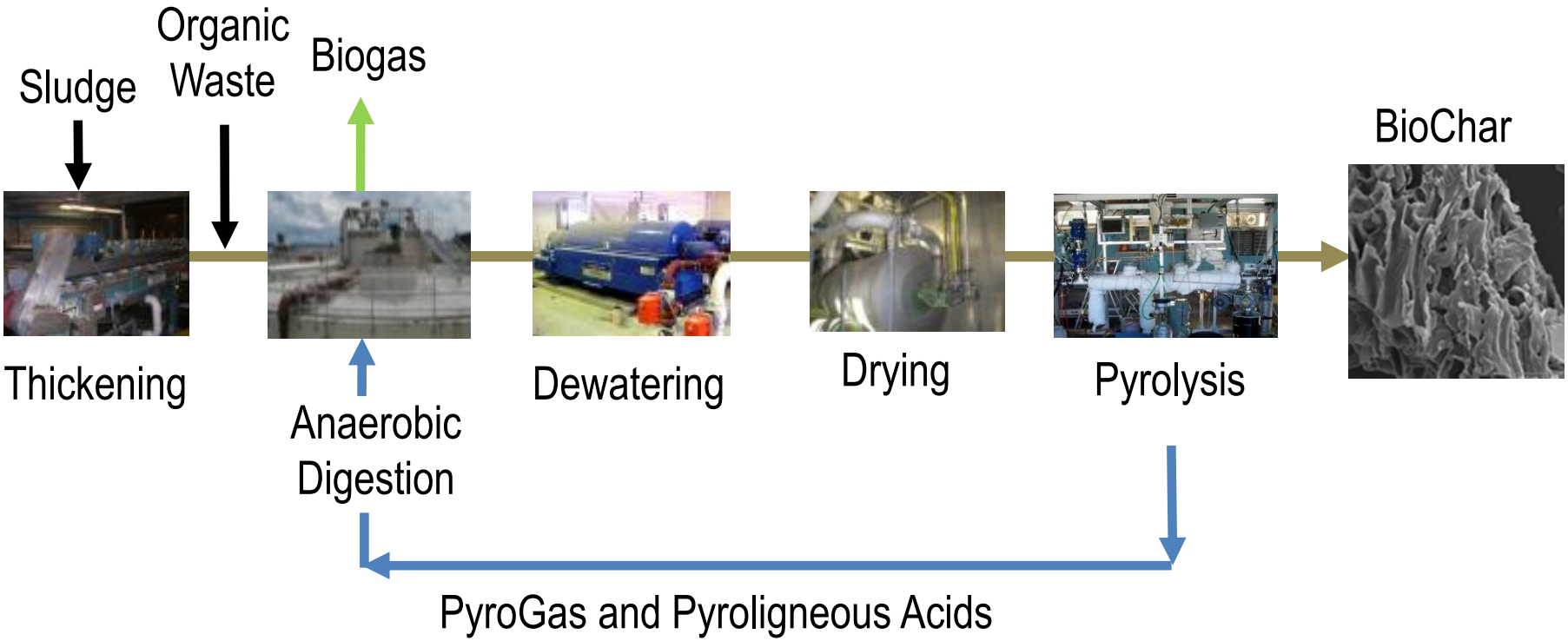
Biosolids as a Resource



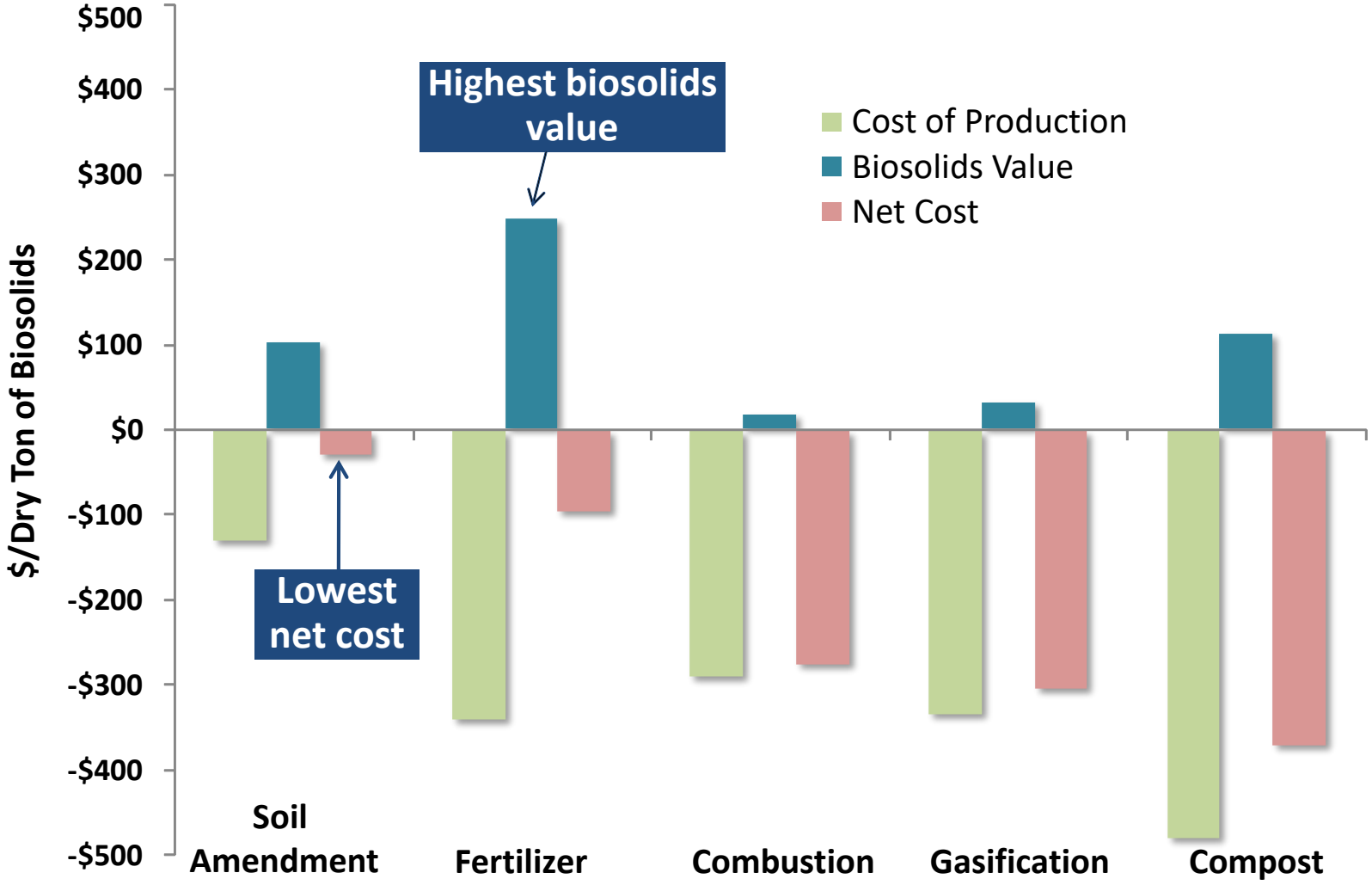
Biosolids Alternatives



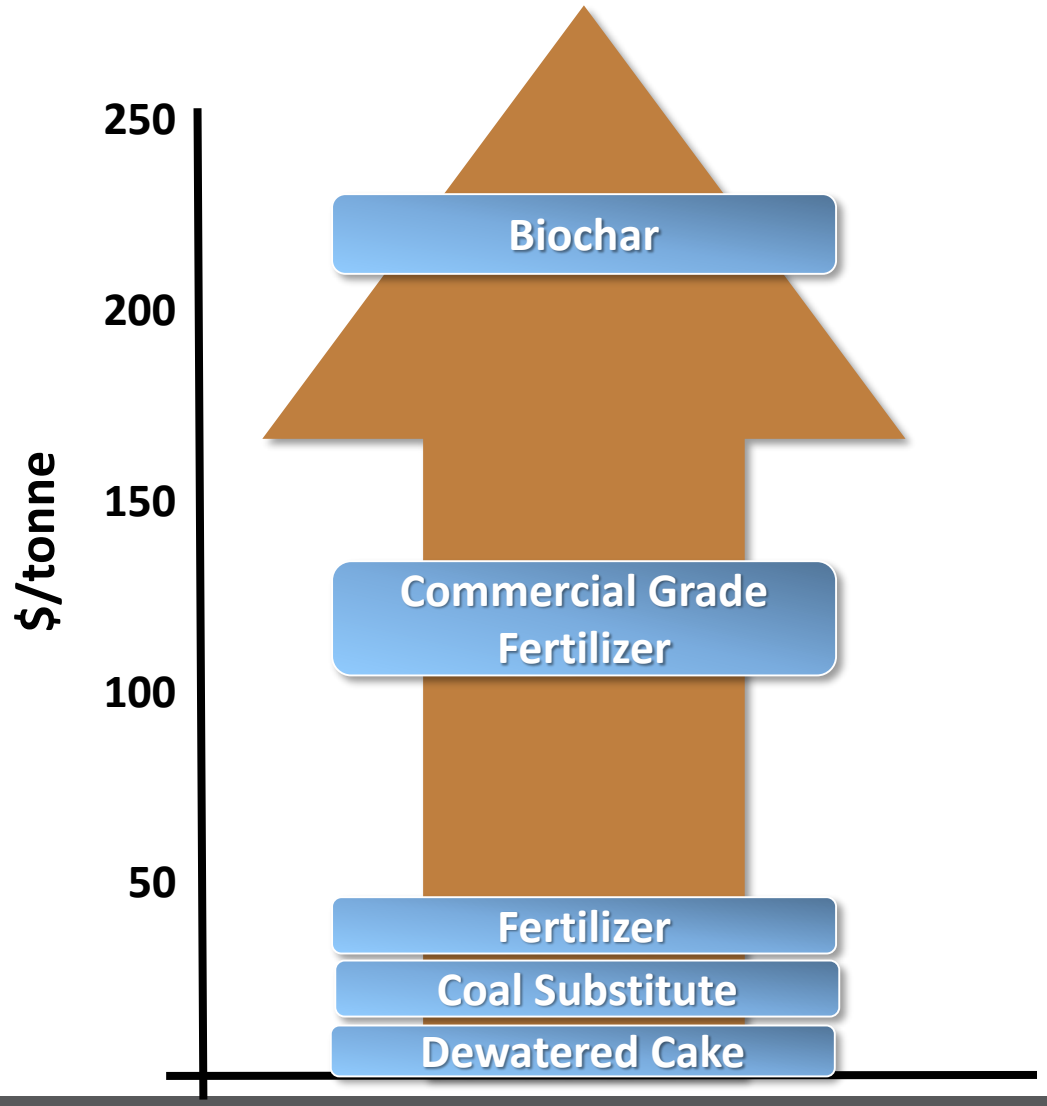
Combined Biological and Thermal Processes



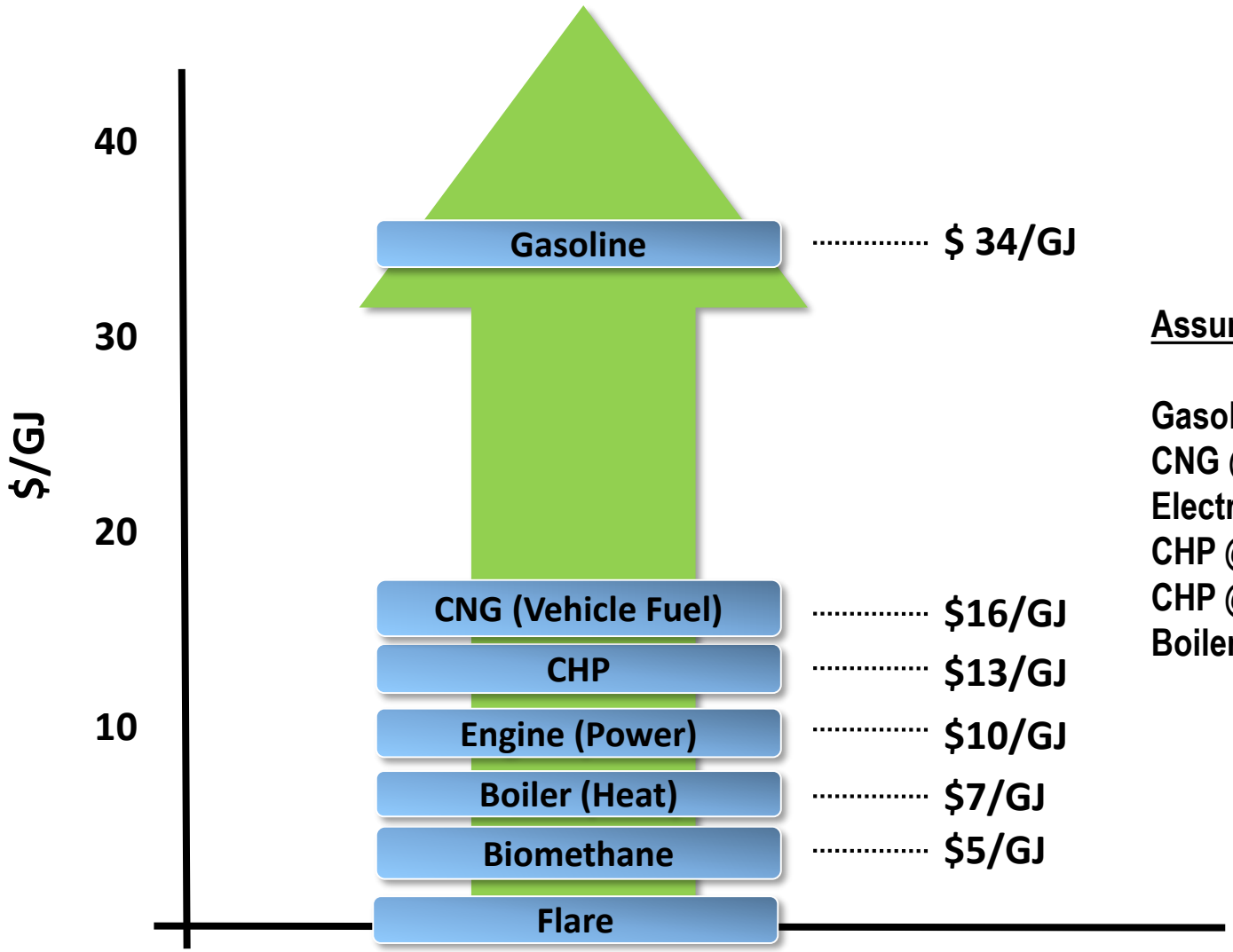
Biosolids Value



Biochar has Highest Value



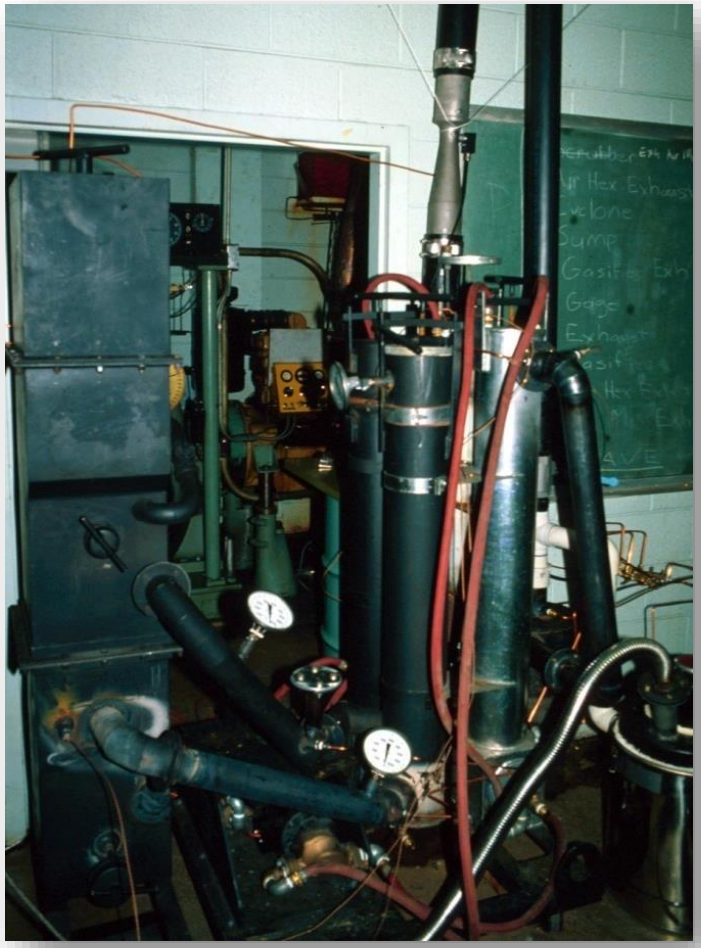
Biogas Value is Dependent on End Use

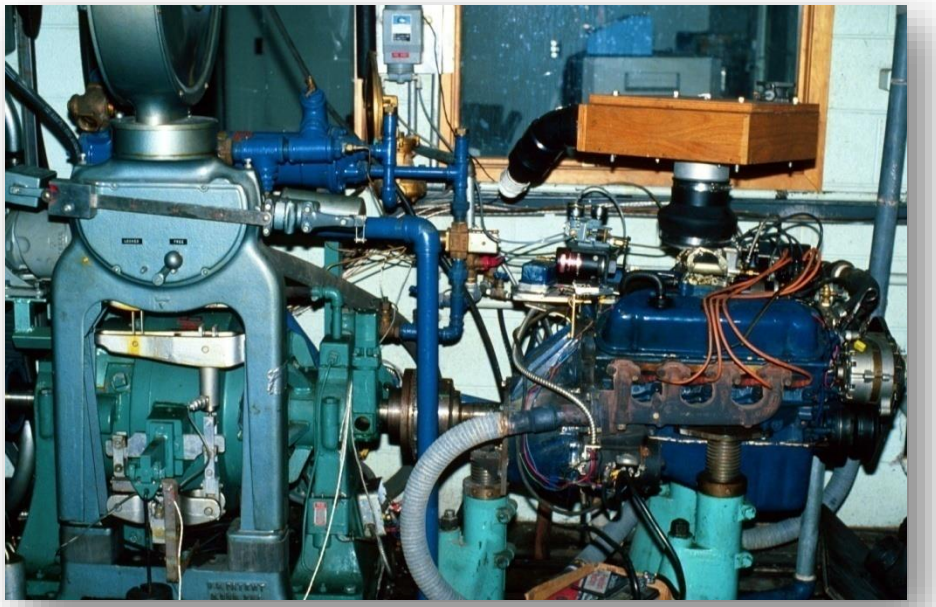


Assumptions:

Gasoline @ $4/gallon
CNG @ $1.85/GGE
Electricity @ $0.10/kWh
CHP @ 35% electric efficiency
CHP @ 40% heat efficiency
Boiler @ 85% efficiency

Gasification and Syngas Research

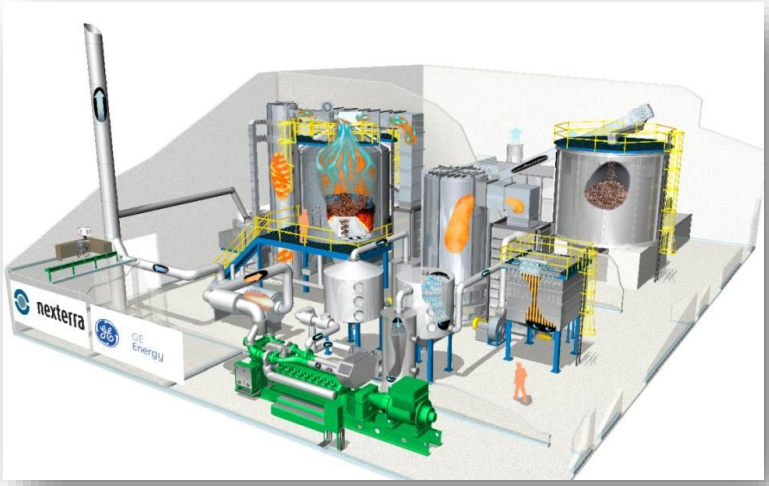


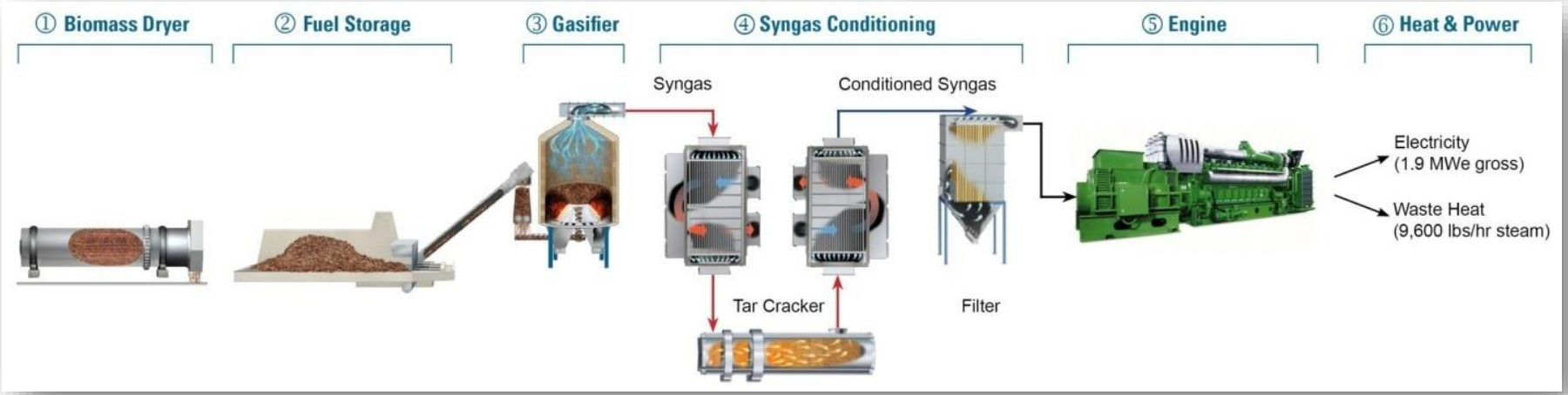


Pilot Plant to test syngas composition, gas cleaning, and fueling an internal combustion engine

Conceptual Syngas Fueled CHP System

- Gasifier fueled from Biomass (wood waste diverted from landfill)
- Cutting edge syngas conditioning technology
- Internal Combustion Engine 2 MW Combined Heat and Power system
- Recovered heat used to dry biosolids

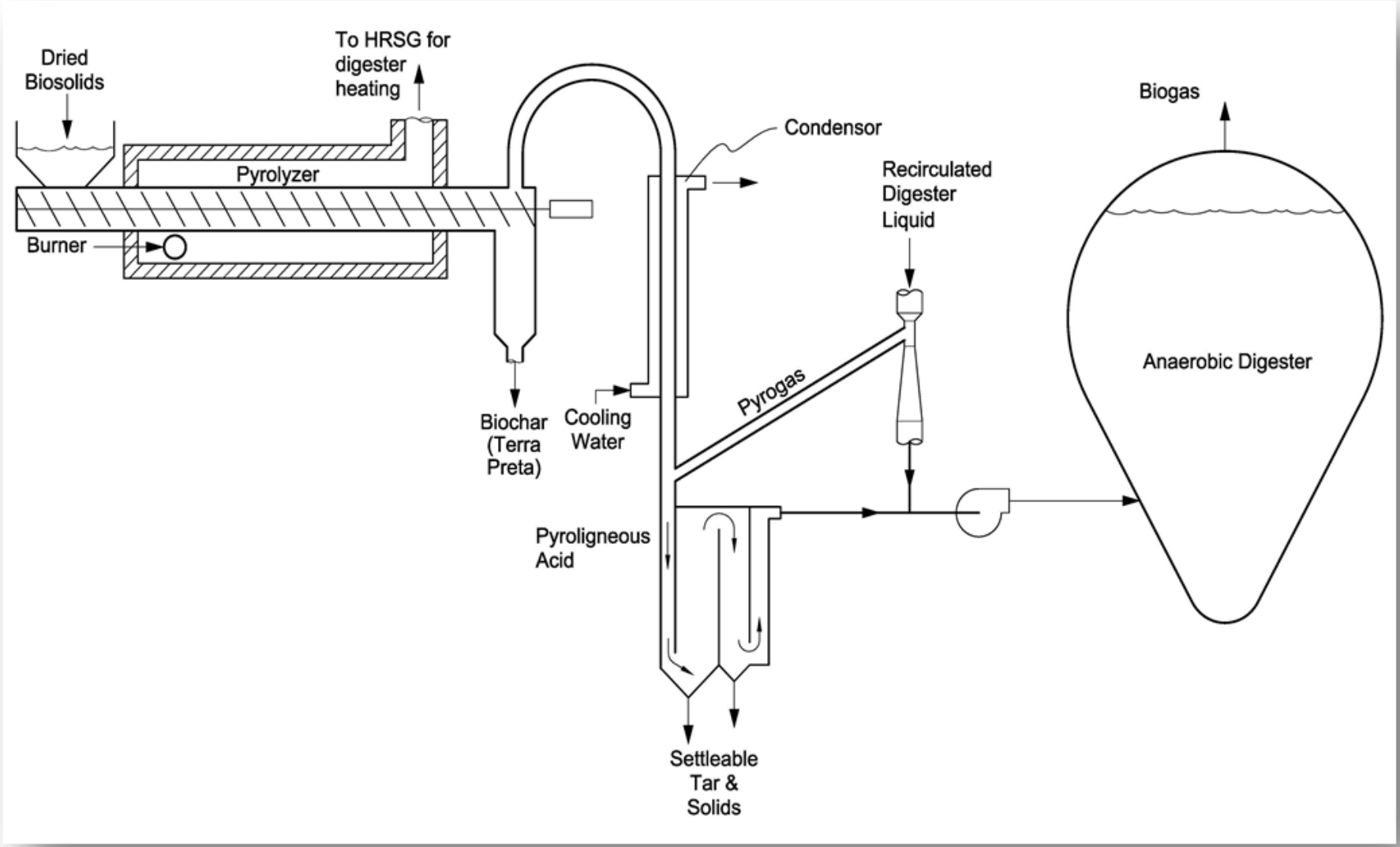




The PyroBioMethane Process

- Slow, low temperature pyrolysis process
- Converts recalcitrant lignins and other organics in dried, digested biosolids into:
  - Pyroligneous acid consisting of water soluble organic compounds and oils.
  - Pyrogas consisting primarily of CH_4, H_2, CO, and CO_2
  - Solid carbonaceous biochar product
  - Pyrogas is combined with biogas where proven gas treatment technology can be used
  - Pyroligneous acid is fed to the anaerobic digester to produce more biogas

PyroBioMethane Process

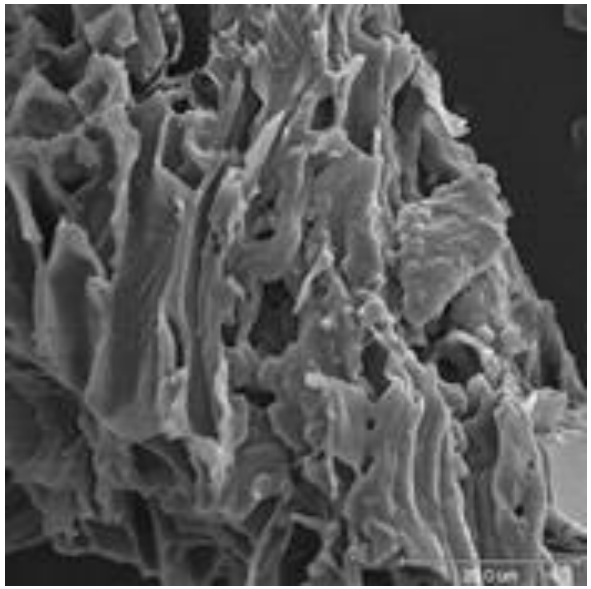


How the Process Works

- Maximizes the production of wood vinegar (acetic acid), wood alcohol (methanol) and other water soluble organic compounds
- Water soluble organic liquids, “water-of-pyrolysis” and Pyrogas are then introduced back into the digester and converted into biogas
- Dried biosolids are converted to biochar and pyrogas in the pyrolyzer.
- Both pyroligeneous acid (condensate) and non-condensable gases are fed to the anaerobic digester

Numerous Biochar Benefits

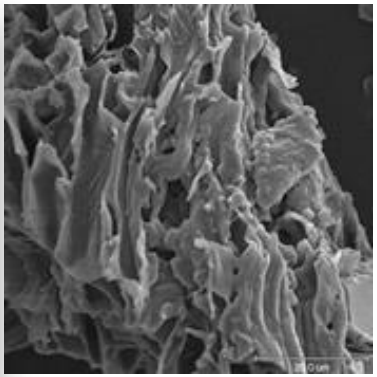
- Soil amendment like Terra preta (dark earth)
- Attracts and holds moisture, nutrients (nitrogen and phosphorous)
- Immense surface area provides secure habitat for microorganisms
- Enhances crop yield
- Enriches soil & protects water



Microscopic view of biochar surface

Pyrobiomethane Process Goals

- Reduce the amount of residual biosolids
- Reduce odor of biosolids product
- Create high value biochar product
- Increase biogas production for beneficial use using proven gas treatment technology



Pyrolysis Research Pilot

- Digested sludge and thickened sludge were collected from King County's South Treatment Plant in Renton, WA
- Dried biosolids (SoundGro) were collected from Pierce County's Chambers Creek Regional Wastewater Treatment Plant in University Place, WA

Pyrolysis Research Pilot

Pyrolysis Pilot

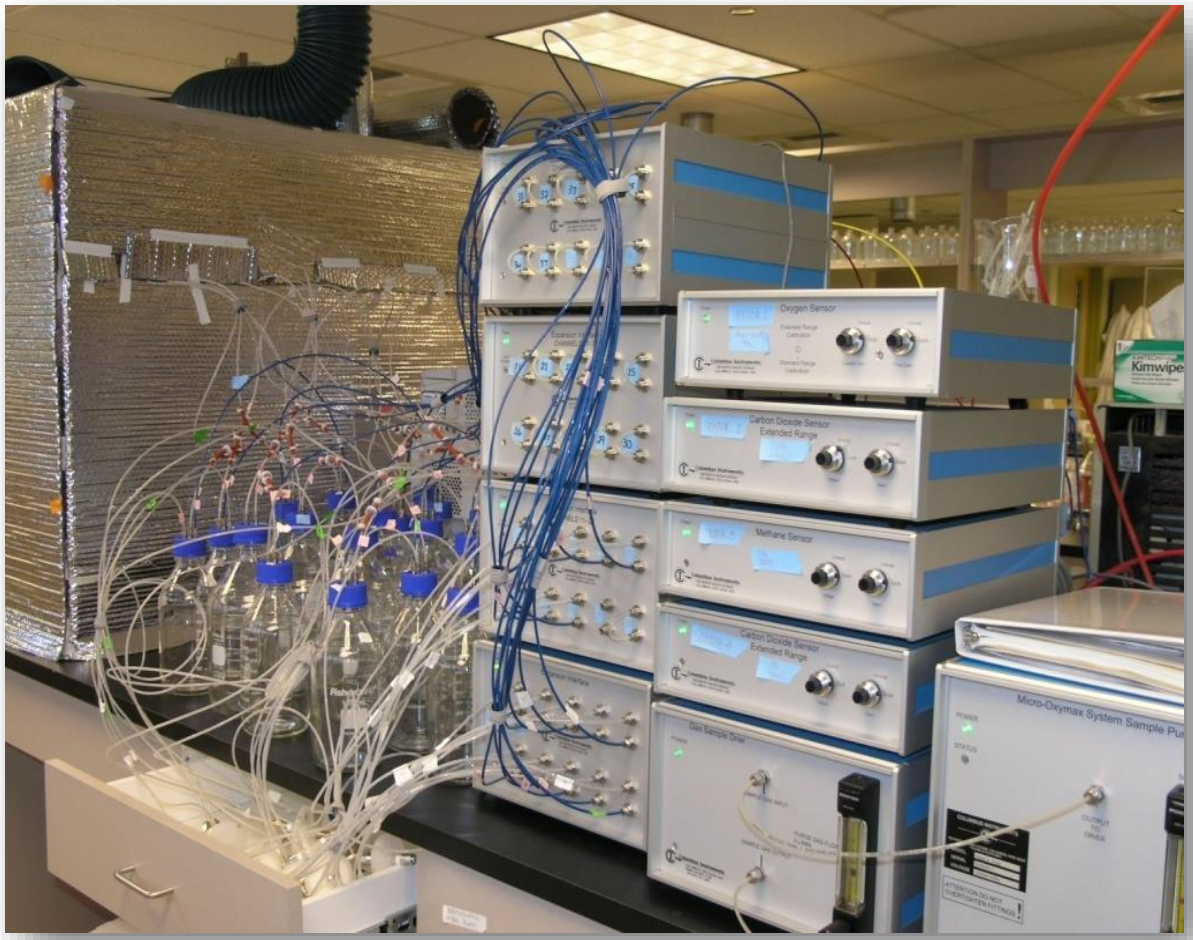
Pyroligneous Acid from Pyrolysis Pilot

Pyroligneous Acid Characterization and BMP

- Total solids, volatile solids, total COD, soluble COD, TKN and density analysis
- Sampled on the initial and final day of the BMP for pH, soluble and total COD, total and volatile solids, and alkalinity

CDM Smith Lab, Bellevue, WA

Columbus Instruments Respirometer System



Results Summary of SoundGro and Pyrolyzed SoundGro Product COD and TKN

Sample	Total COD	TKN
Dried Biosolids (Soundgro)	1,010,000 mg/kg	84,300 mg/kg
Condensate	752,000 mg/kg	11,200 mg/kg
Biochar	694,000 mg/kg	204,000 mg/kg

Results of Biomethane Potential Tests

Digester Feed	Methane Produced, mL
Digested sludge only	120
Digested sludge + thickened sludge	300
Digested sludge + thickened sludge + condensate	350
Digested sludge + thickened sludge + biochar	370
Digested sludge + thickened sludge + condensate + biochar	360
Digested sludge + thickened sludge + dried biosolids	410
Digested sludge + thickened sludge + sodium acetate	650

Energy Value of Dried Biosolids and Pyrolyzed Products

Product	Units	Energy Value
Dried Biosolids	kJ/kg (BTU/lb)	16,400 (7,070)
Biochar	kJ/kg (BTU/lb)	18,600 (8,010)
Heavy Oil	kJ/kg (BTU/lb)	<460 (<200)
Intermediate Oil	kJ/kg (BTU/lb)	24,700 (10,700)
Light Oil	kJ/kg (BTU/lb)	35,300 (15,200)
Mixed Oil	kJ/kg (BTU/lb)	5,660 (2,440)

Lab Results

- Pyrolysis resulted in a 46 percent reduction in solids
- Dried biosolids had COD value of 1,010,000 mg/kg and the condensate and biochar had comparable values of 752,000 and 694,000 mg/kg
- Biochar had a much higher TKN value (204,000 mg/kg) compared to the dried biosolids (84,300 mg/kg) indicating a concentrating effect from the pyrolysis
- All digester feed products increased the methane produced compared to the baselines of digested sludge only (120 mL) and digested sludge + thickened sludge (300 mL)
- Pyrolysis increased the energy content from16,400 kJ/kg in the dried biosolids to 18,600 kJ/kg in the biochar

Summary

- PyroBioMethane process has the potential to:
  - Enhance anaerobic digestion
  - Produce more biogas
  - Reduce the amount of the residual biosolids
- Convert biosolids to a biochar which has:
  - Improved soil amendment characteristics
  - Less odor

Next Step: PyroBioMethane Demonstration Encina Water Pollution Control Facility

Four 750 kW Engine-Driven Generators

Rotary Drum Dryer

Pyrobiomethane Pros and Cons

- Economic
  - PROS: More biogas, high value biochar product
  - CONS: Requires dewatering and drying before pyrolysis
- Operational
  - PROS: Proven Technology, e.g., use of proven biogas treatment instead of cutting edge syngas treatment
  - CONS: Potentially stronger sidestream from dewatering

Economic

Operational

Pyrobiomethane Pros and Cons

- Environmental
  - PROS: Renewable biogas production, carbon footprint, nutrient rich soil amendment
  - CONS: Produces potentially toxic compounds from pyrolysis of digested biosolids

- Social
  - PROS: Less odorous product
  - CONS: Greater odor strength if released during the process

Questions and Answers

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